Geographic Variation of Mercury Content, and Mercury Emissions Predicted For Existing Technologies, by U.S. County of Coal Origin

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contract manager: Sara Pletcher

Project Website:
http://geology.utah.gov/emp/mercury/index.htm

UTAH GEOLOGICAL SURVEY

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Selected Coal Data

25,825 records ICR 2 data (1999)
<epa.gov/ttn/atw/combust/utiltox/utoxpg.html>

19,507 records FERC 423 data (1999)
<eia.doe.gov/cneaf/electricity/page/ferc423.html>

5,823 records FERC 580 data (1992 to 1999)
<eia.doe.gov/cneaf/coal/ctrdb/database.html>

5,059 records COALQUAL data (1973 to 1989)
Bragg, L.J., and others 1997, U.S. Geological Survey Open File Report 97-134.

1,342 records MSHA data (1999)
<http://www.msha.gov/STATS/PART50/P50Y2K/A&I/1999/caim1999.exe>

73 records DOE-PSU data (1985 to 1995)
Davis, A., and Glick, D.C., 1993, U.S. DOE contract DE-RP22-87PC79997
Scaroni, A.W., and others, 1999, U.S. DOE contract DE-AC22-93PC93051

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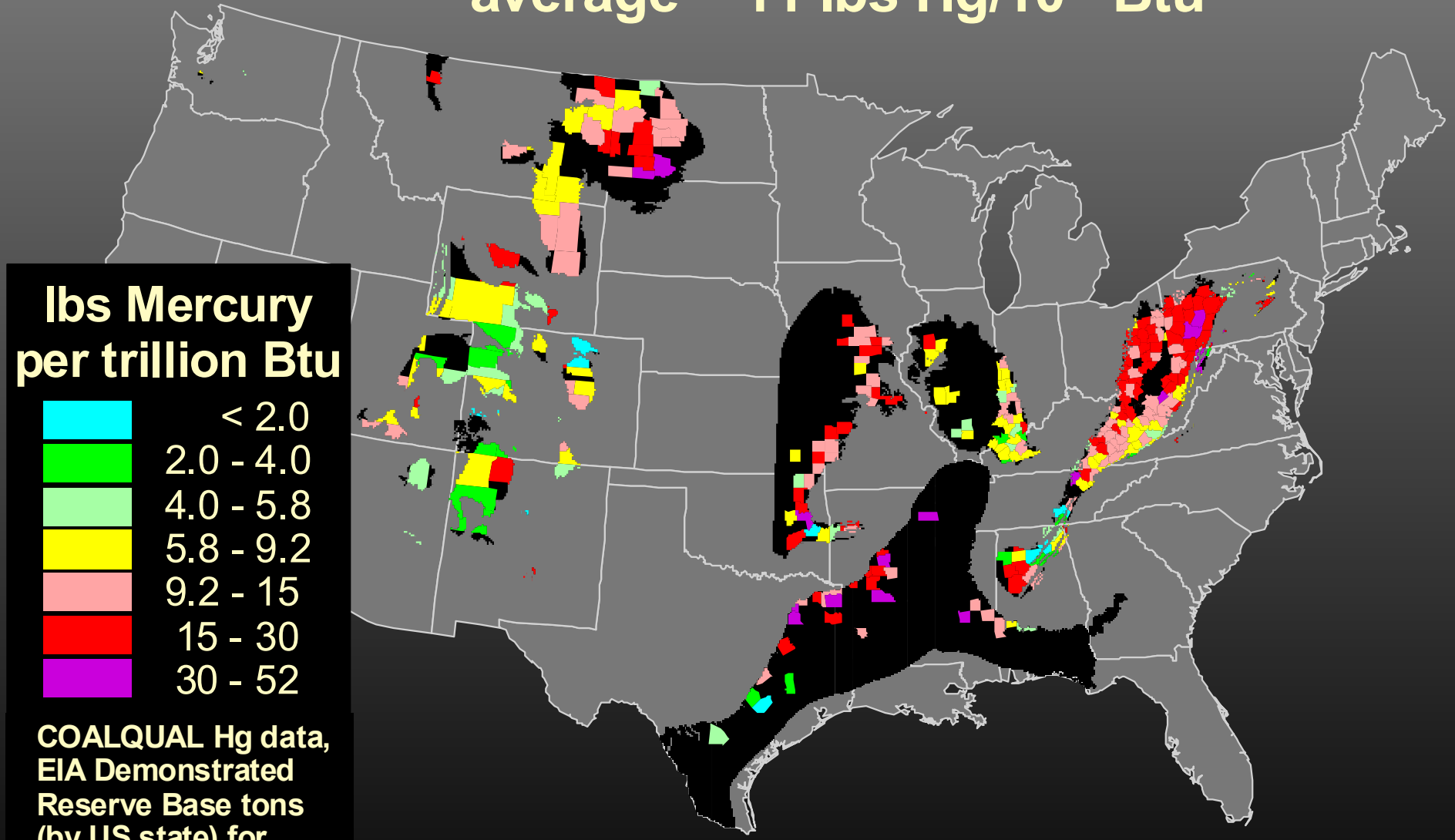
In-ground Coal Mercury

average ~ 11 lbs Hg/10^{12}Btu



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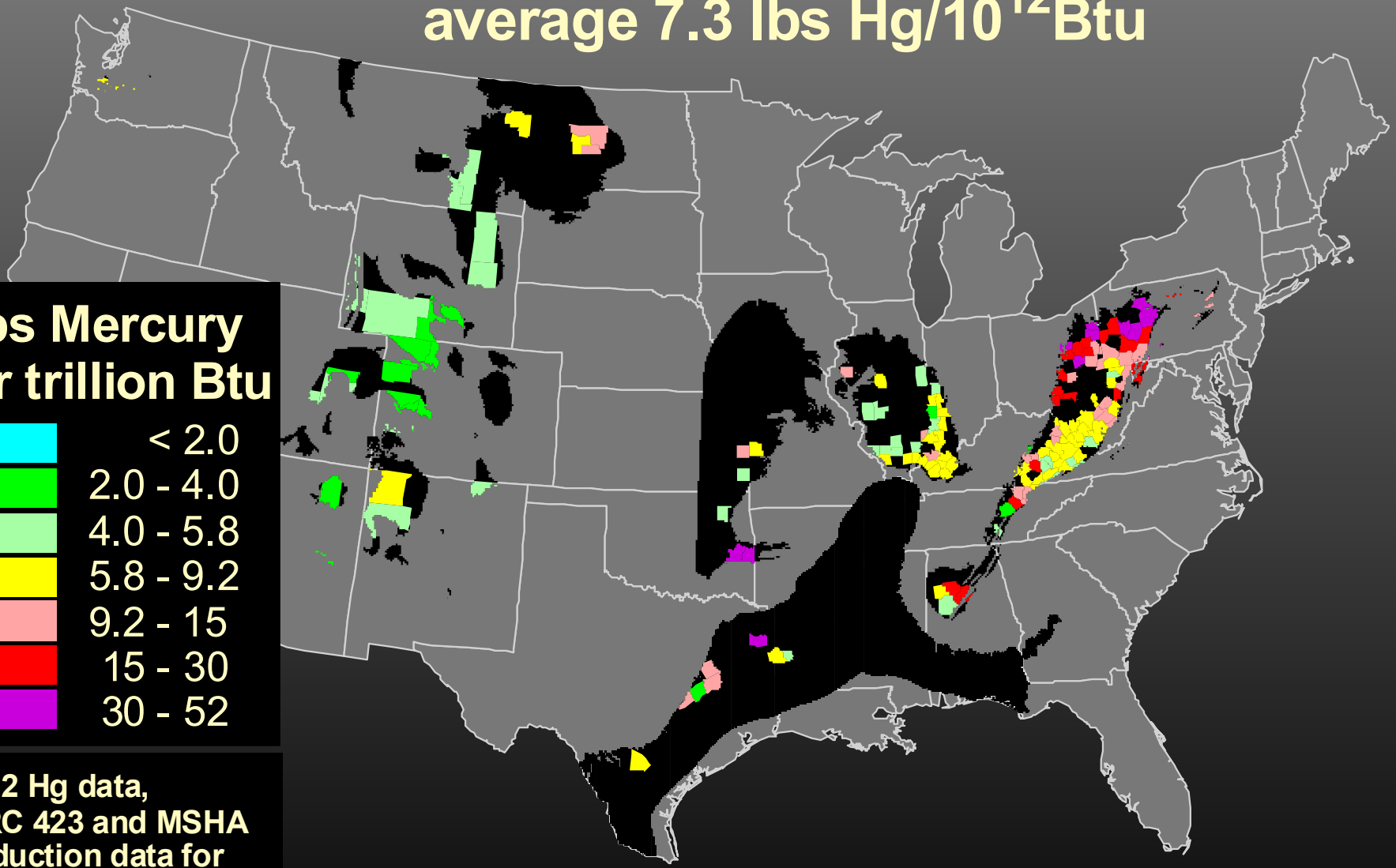
Produced Coal Mercury

average 7.3 lbs Hg/10^{12}Btu



ICR 2 Hg data, FERC 423 and MSHA production data for tonnage-weighted average Hg calculation.

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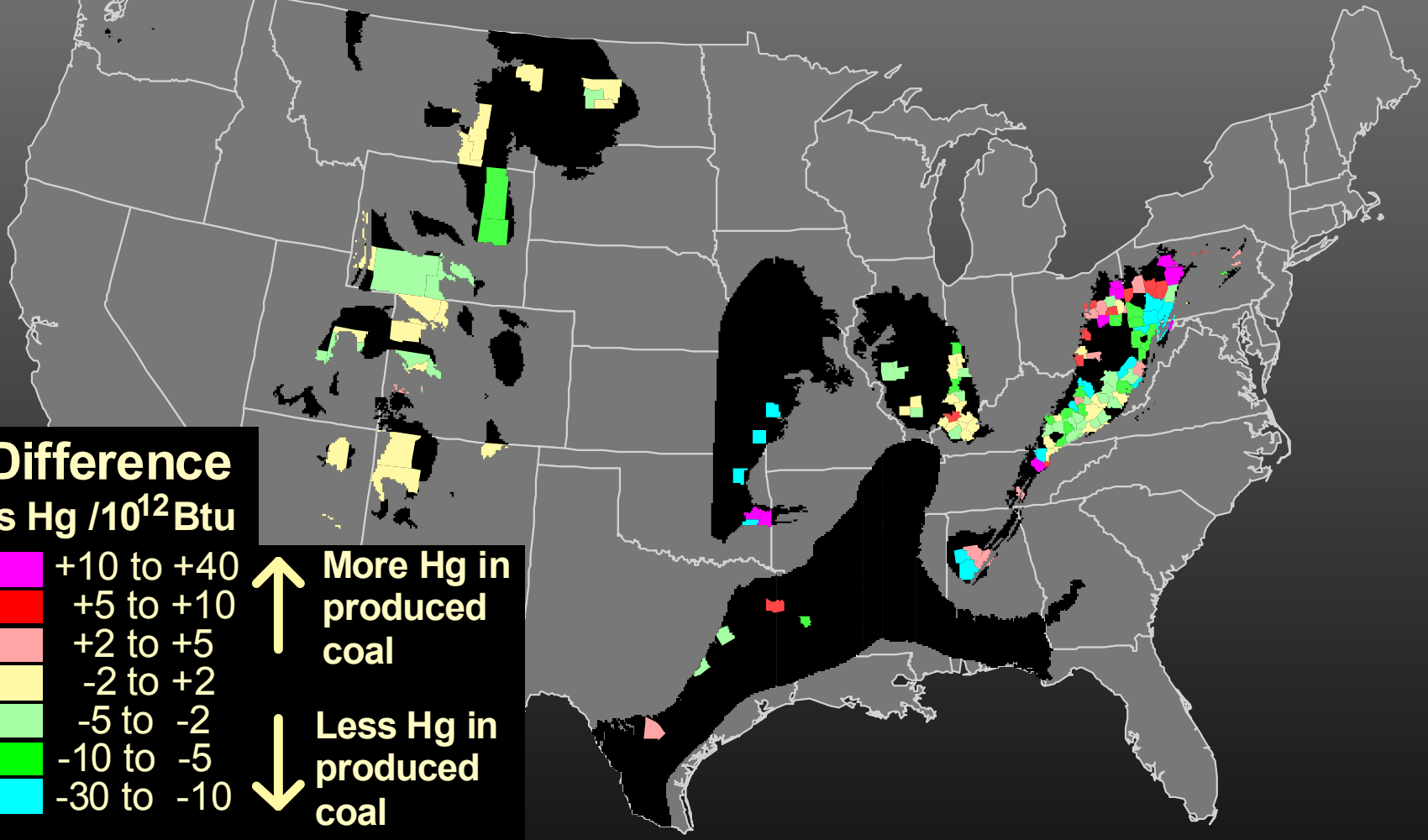
Produced minus In-ground Coal Mercury

7.3 - 11.2 = -3.9 lbs Hg/10^{12}Btu



COALQUAL and ICR Hg data for coincident counties, FERC 423 and MSHA production data for tonnage-weighted average Hg.

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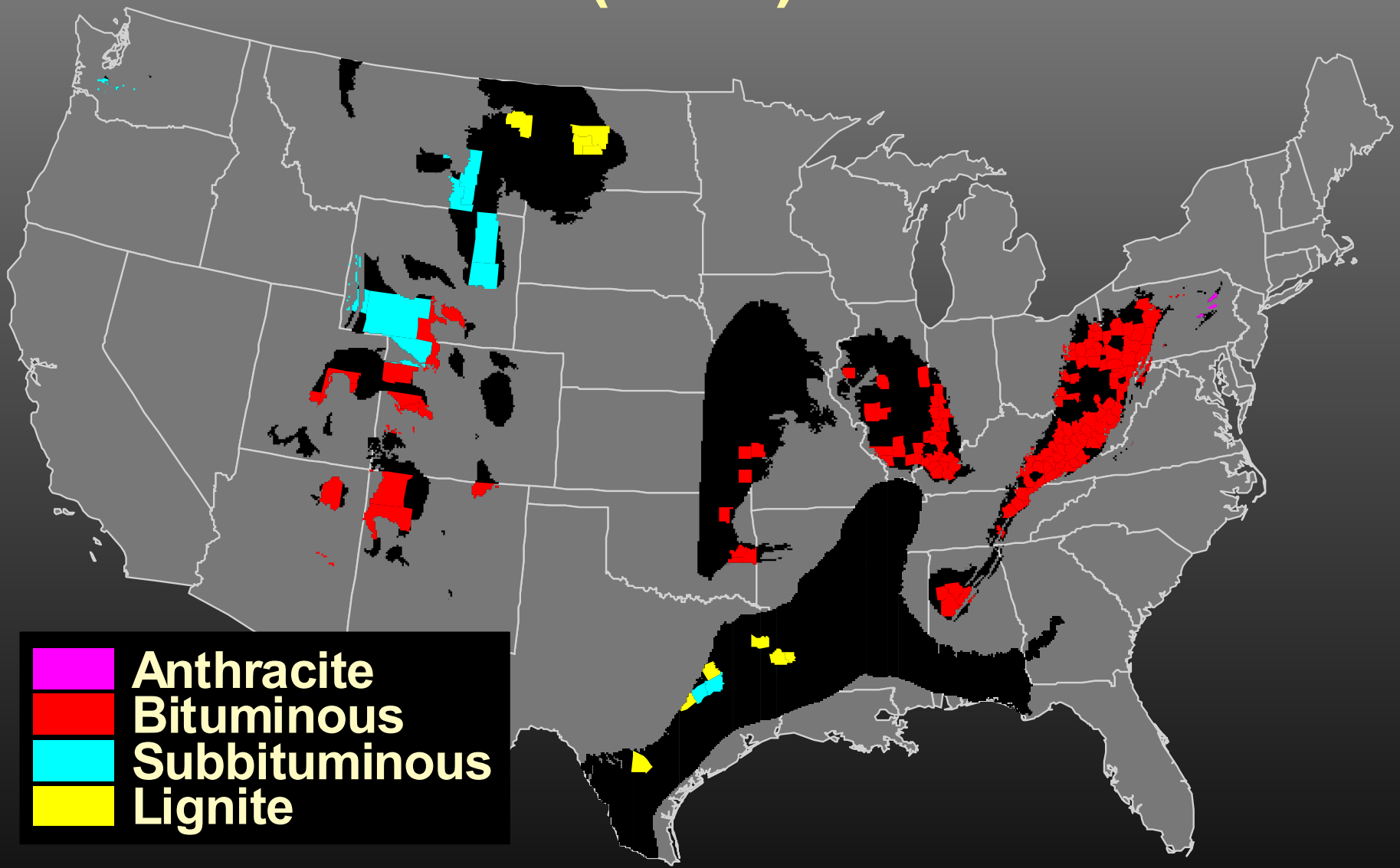
2004 Proposed Mercury Rule MACT option, existing units

	lbs Hg per trillion BTU		10^{-6} lbs Hg per MWH
bituminous	2.0	or	21
subbituminous	5.8	or	61
lignite	9.2	or	98
IGCC	19	or	200
refuse	0.38	or	4.1

ASTM (1990) Coal Rank



ICR 2 county averages calculated using data from: FERC 423, FERC 580, and ICR 2 (with estimated moisture)

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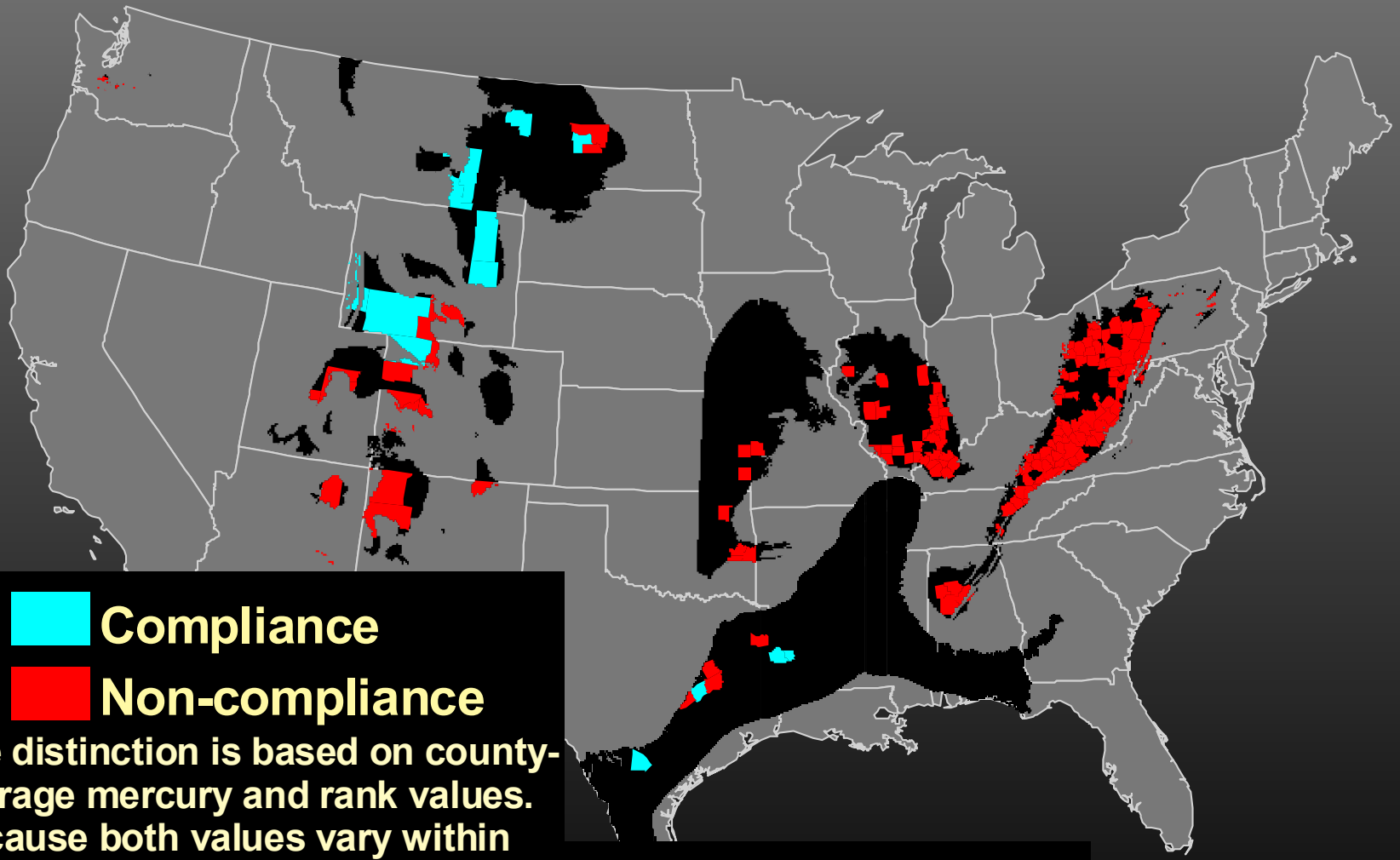
Mercury Compliance Coal
existing PC units, MACT rule, no Hg capture



Compliance

Non-compliance

The distinction is based on county-average mercury and rank values. Because both values vary within counties, the map is indicative, rather than diagnostic, of Hg compliance coal. County-average Hg from ICR2; rank class from FERC-423, -580, and ICR 2 (moisture estimated).

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Electric Utility Data

240 records ICR 3 data (1999)

<epa.gov/ttn/atw/combust/utiltox/utoxpg.html>

SAIC 2003, Calculation of possible mercury MACT floor values for coal-fired utilities - influence of variability and approach. <netl.doe.gov/coal/E&WR/mercury/pubs/DOE_Report_v120803.pdf>

ENSR 2003, Multivariable method to estimate the mercury emissions of the best-performing coal-fired utility units. <epa.gov/ttn/atw/combust/utiltox/final_ensr_multivar.pdf>

Roberson 2002, UARG variability analysis. <epa.gov/ttn/atw/combust/utiltox/epavarifnl.doc>

561 records CEA data

Canadian Electricity Association, <ceamercuryprogram.ca/EN/sampling_data.html> preliminary Oct. 2004 data

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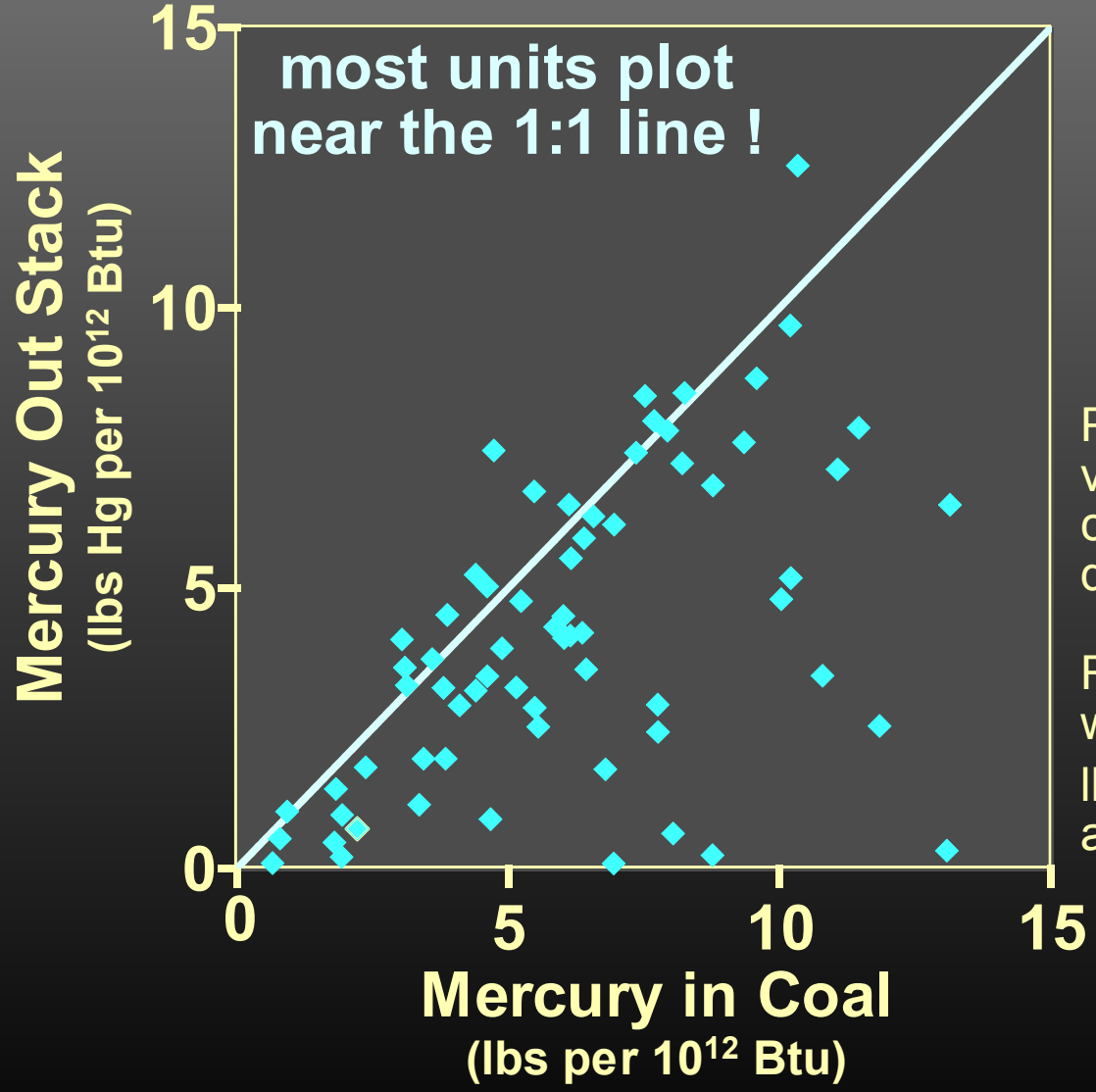
Mercury in ≈ Mercury out



Points show average values for 67 pulverized coal fired units, ICR 3 data.

Results for 4 units where mercury is >15 lbs Hg per 10^{12} Btu are ignored.

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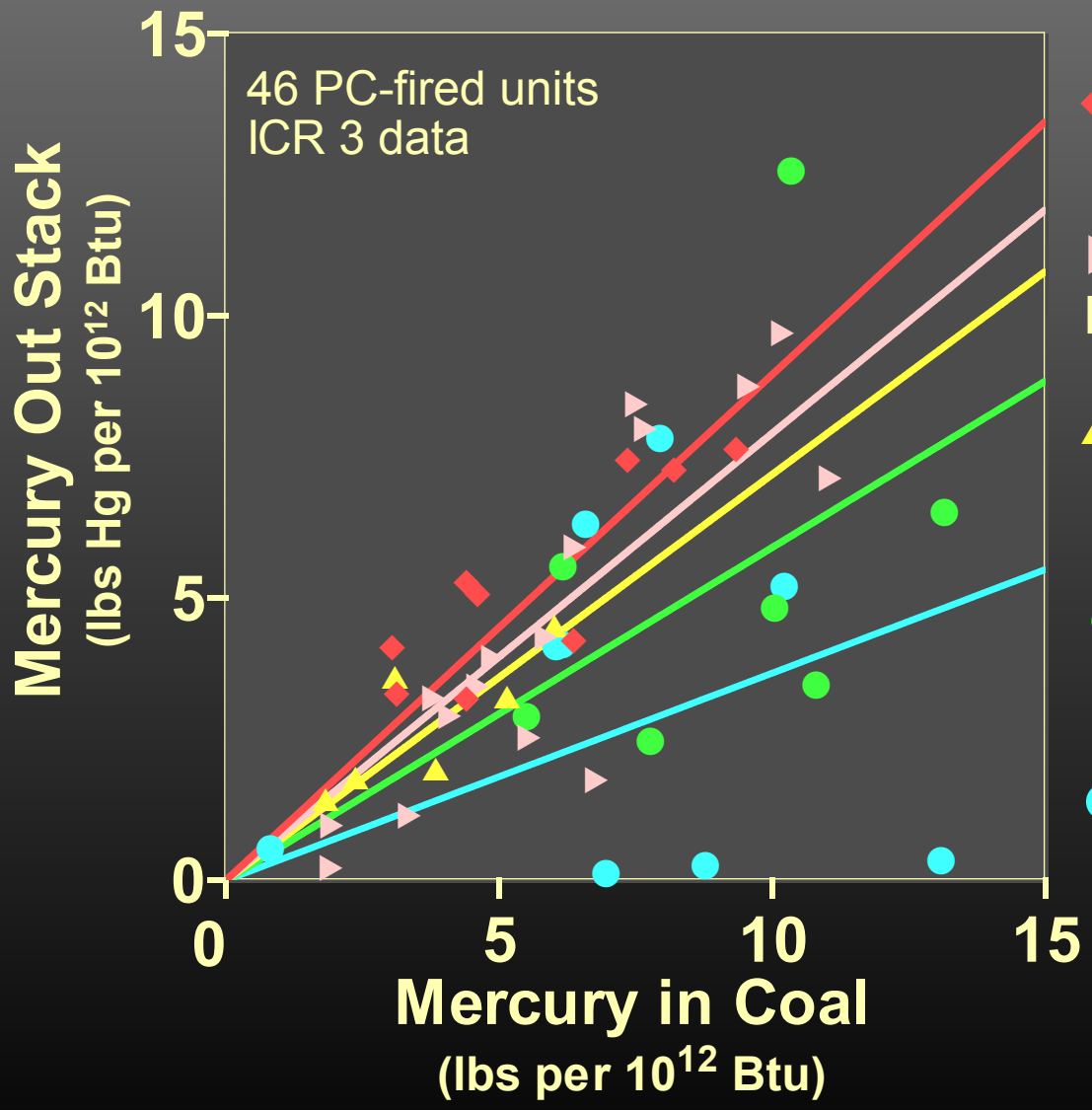
The significance of the coal mercury content depends on the emission control technolgy



- **hot ESP**
  $Hg_{out} = 0.90\ Hg_{in}$; $r^2 = 0.75$
- **cold ESP**
  $Hg_{out} = 0.79\ Hg_{in}$; $r^2 = 0.76$
- **hot ESP FGD**
  $Hg_{out} = 0.72\ Hg_{in}$; $r^2 = 0.65$
- **cold ESP FGD**
  $Hg_{out} = 0.59\ Hg_{in}$; $r^2 = 0.15$
- **SDA fabric filter**
  $Hg_{out} = 0.38\ Hg_{in}$; $r^2 = 0.00$

UTAH GEOLOGICAL SURVEY

equations that predict SDA Fabric Filter Hg capture* (ICR 3 data)

applied to average coal assay data for 161 U.S. counties** (ICR 2 data)

excellent fits !
similar trends !
BUT. . .
different results !

- **SAIC 1; R^2 = 0.89**

  1-Exp(10.711 - 1.2263Ln(lbs Cl per 10^{12} Btu))
  n = 10

- **ENSR; R^2 = 0.94**

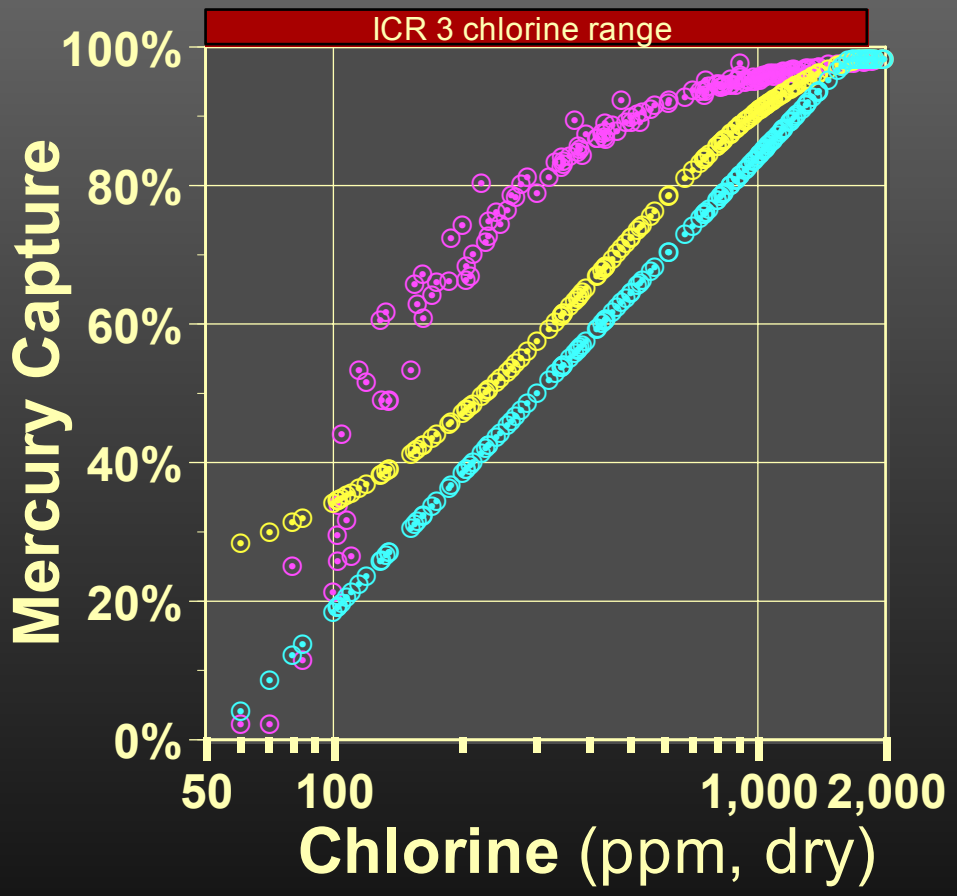
  $1-0.8188Exp(-2.164E^{-3}Ln(Cl_{ppm,dry}))$
  n = 10

- **Roberson; R^2 = 0.91**

  $0.2854Ln(Cl_{ppm,dry}) - 1.1302$

n = 10
* Results limited to 98% maximum and 2% minimum capture values.

** Not shown:6 counties with Cl >2,000 ppm and 1 county with Cl <50 ppm.



UTAH GEOLOGICAL SURVEY

equations that predict Cold ESP FGD Hg capture* (ICR 3 data)

applied to average coal assay data for 161 U.S. counties** (ICR 2 data)

good fits !

similar trends !

different results !

- **SAIC 3; $R^2 = 0.73$**

  $1\text{-Exp}(-0.2559 - 2.334E^{-5}(100Cl_{ppm,dry} / S_{\%dry}))$

  n = 8

- **SAIC 1; $R^2 = 0.74$**

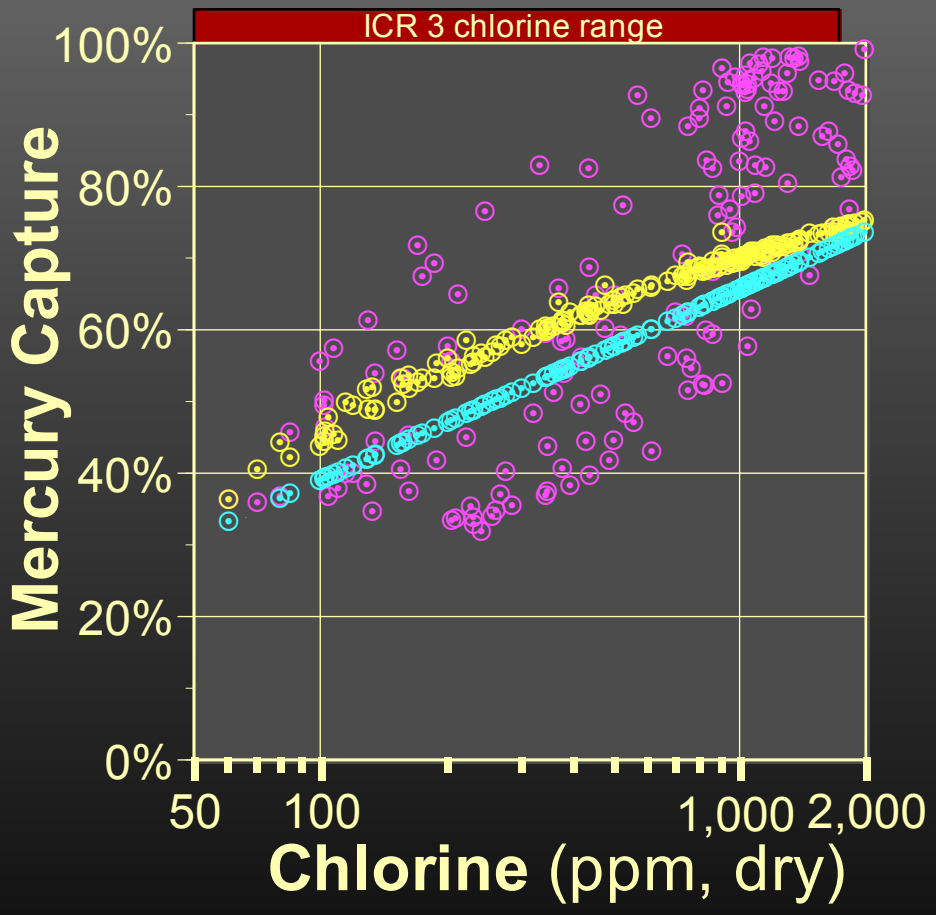
  $1\text{-Exp}(1.8529 - 0.27149\text{Ln}(\text{lbs Cl per } 10^{12} \text{ Btu}))$

  n = 8

- **Roberson; $R^2 = 0.70$**

  $0.1157\text{Ln}(Cl_{ppm,dry}) - 0.1438$

  n = 11



* Results limited to 98% maximum, and 2% minimum capture values.

** Not shown: 6 counties with Cl >2,000 ppm, and 1 county with Cl <50 ppm.

UTAH GEOLOGICAL SURVEY

equations that predict Hot ESP FGD Hg capture* (ICR 3 data)

applied to average coal assay data for 161 U.S. counties** (ICR 2 data)

modest fits !

similar trends !

different results !

- **SAIC 1; R^2= 0.75**

  1-Exp(2.7019 - 0.29952Ln(lbs Cl per 10^{12} Btu))

  n = 6

- **SAIC 2; R^2= 0.67**

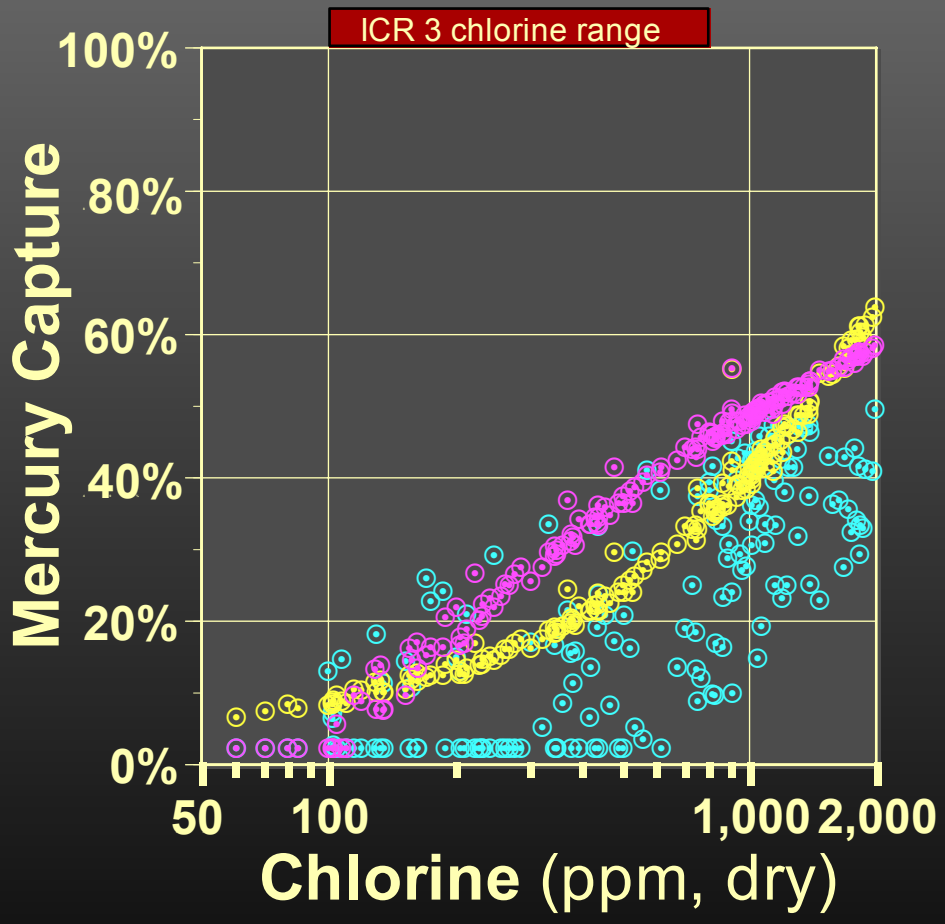
  1-Exp($-3.59E^{-2}$ - $9.358E^{-6}$(lbs Cl per 10^{12} Btu))

  n = 6

- **SAIC 4; R^2= 0.42**

  1-Exp(2.5618 - 0.268Ln(100 $Cl_{ppm,dry}$ / $S_{wt.\%,\ dry}$))

  n = 6



* Results limited to 98% maximum, and 2% minimum capture values.

** Not shown: 6 counties with Cl >2,000 ppm and 1 county with Cl <50 ppm.

equations that predict Cold ESP Hg capture* (ICR 3 data)

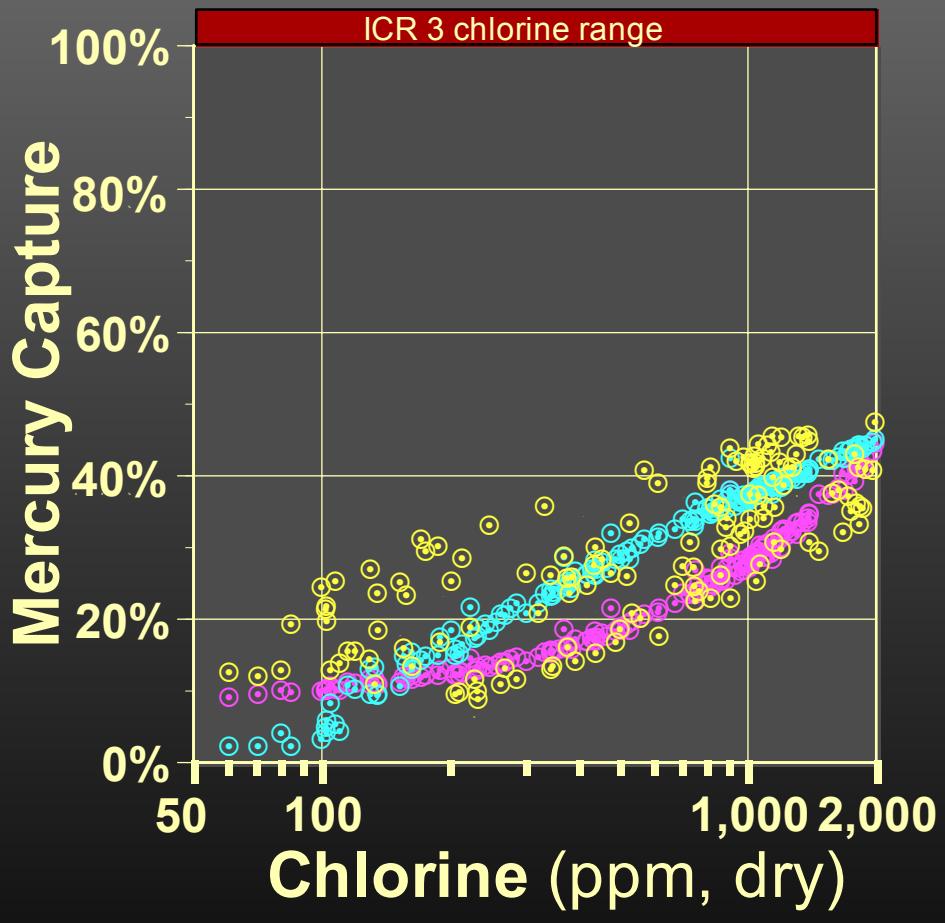
applied to average coal assay data for 161 U.S. counties** (ICR 2 data)

poor fits !

similar trends !

different results !

- **SAIC 2; R^2 = 0.47**
  $1\text{-Exp}(-7.33E^{-2} - 3.309(\text{lbs Cl per } 10^{12} \text{ Btu}))$
  n = 12
- **Roberson; R^2 = 0.53**
  $0.1133\text{Ln}(Cl_{ppm,dry} / 1.998\ S_{wt.\%,dry}) - 0.2987$
  n = 28
- **SAIC 1; R^2 = 0.38**
  $1\text{-Exp}(1.6374 - 0.18693\text{Ln}(\text{lbs Cl per } 10^{12} \text{ Btu}))$
  n = 12



* Results limited to 98% maximum, and 2% minimum capture values.

** Not shown: 6 counties with >2,000 ppm and 1 county with Cl <50 ppm.

equations that predict Hot ESP Hg capture* (ICR 3 data)

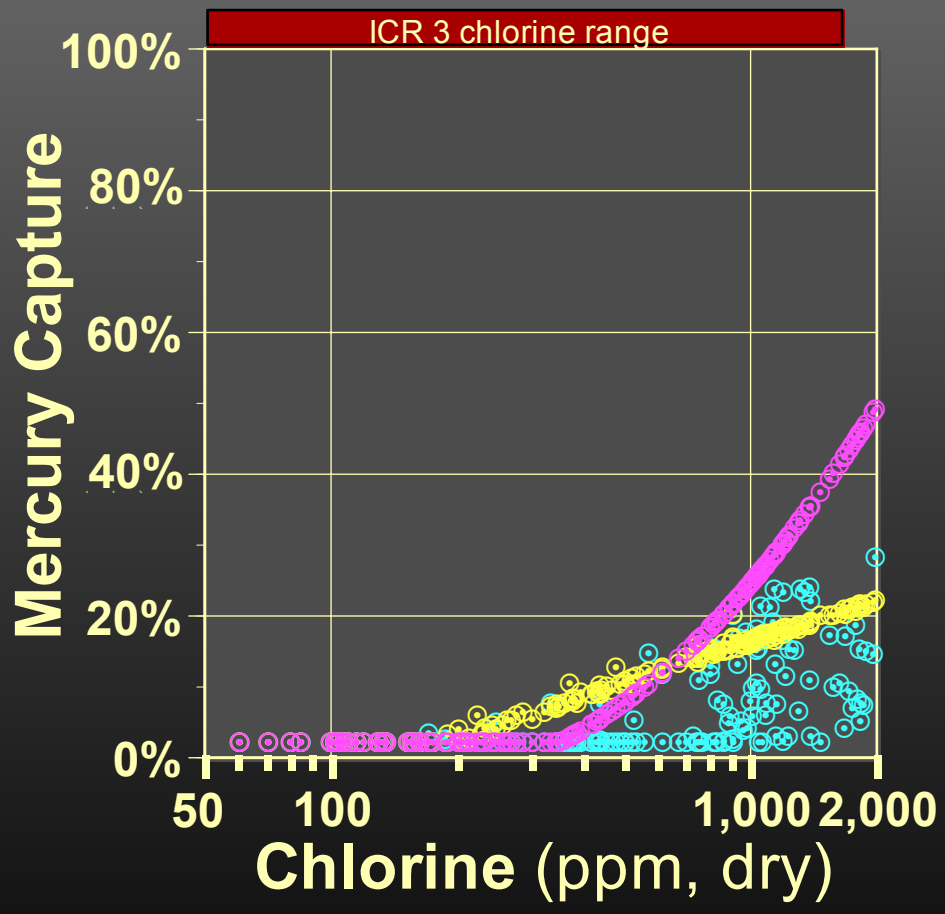
applied to average coal assay data for 161 U.S. counties** (ICR 2 data)

poor fits !

similar trends !

different results !

- **ENSR; R^2 = 0.39**
  $1-Exp(0.12124 - 1.021E^{-4}(Cl_{ppm,dry}))$
  n = 7
- **SAIC 1; R^2 = 0.42**
  $1-Exp(0.9451 - 9.995E^{-2}Ln(\text{lbs Cl per } 10^{12} \text{ Btu}))$
  n = 7
- **SAIC 3; R^2 = 0.54**
  $1-Exp(6.11E^{-2}-2.169E^{-6}(100Cl_{ppm,dry} / S_{\%,dry}))$
  n = 7

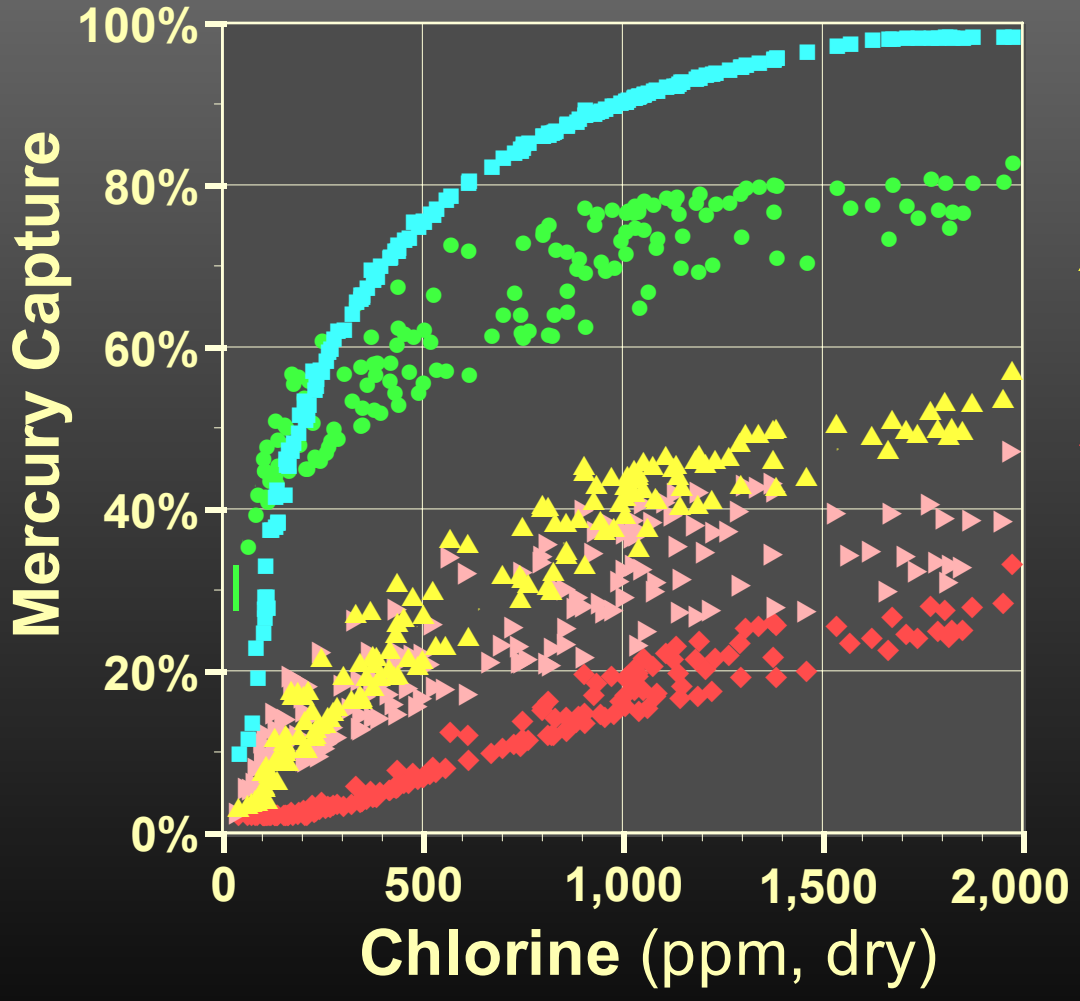


* Results limited to 98% maximum, and 2% minimum capture values.

** Not shown: 6 counties with Cl >2,000 ppm and 1 county with Cl <50 ppm.

Which equation is best?

Average Mercury Capture
Existing Controls, 162 U.S. Counties



- SDA Fabric Filter
- Cold ESP FGD
- Hot ESP FGD
- Cold ESP
- Hot ESP

Mercury capture is the average result from three published equations for each emission control group (ICR 3 data, conventional pulverized coal units).

Points correspond to average coal quality,162 U.S. counties (ICR 2 data).

Not shown are 6 U.S. counties where chlorine exceeds 2,000

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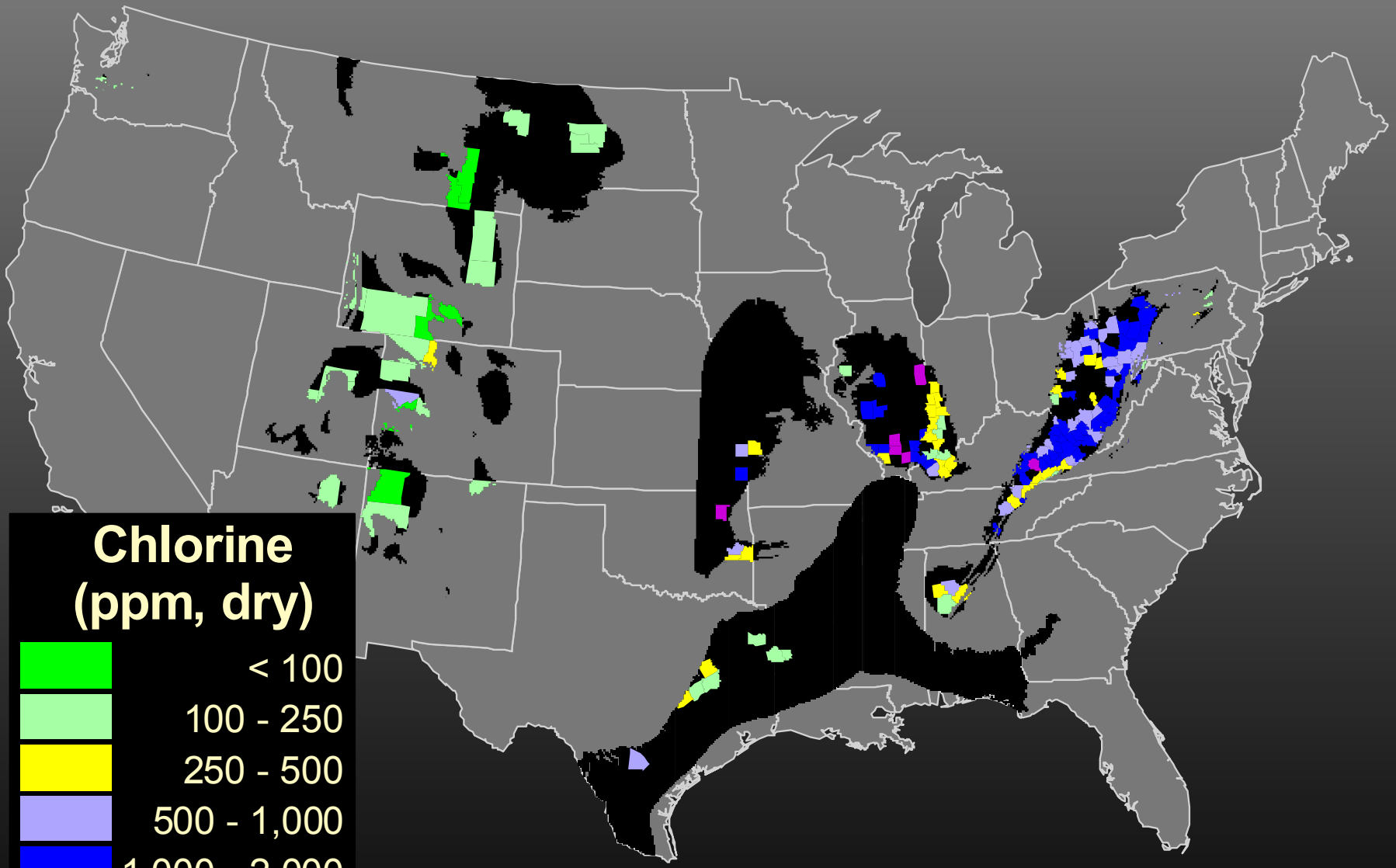
Chlorine in Coal



County average, ICR 2 data

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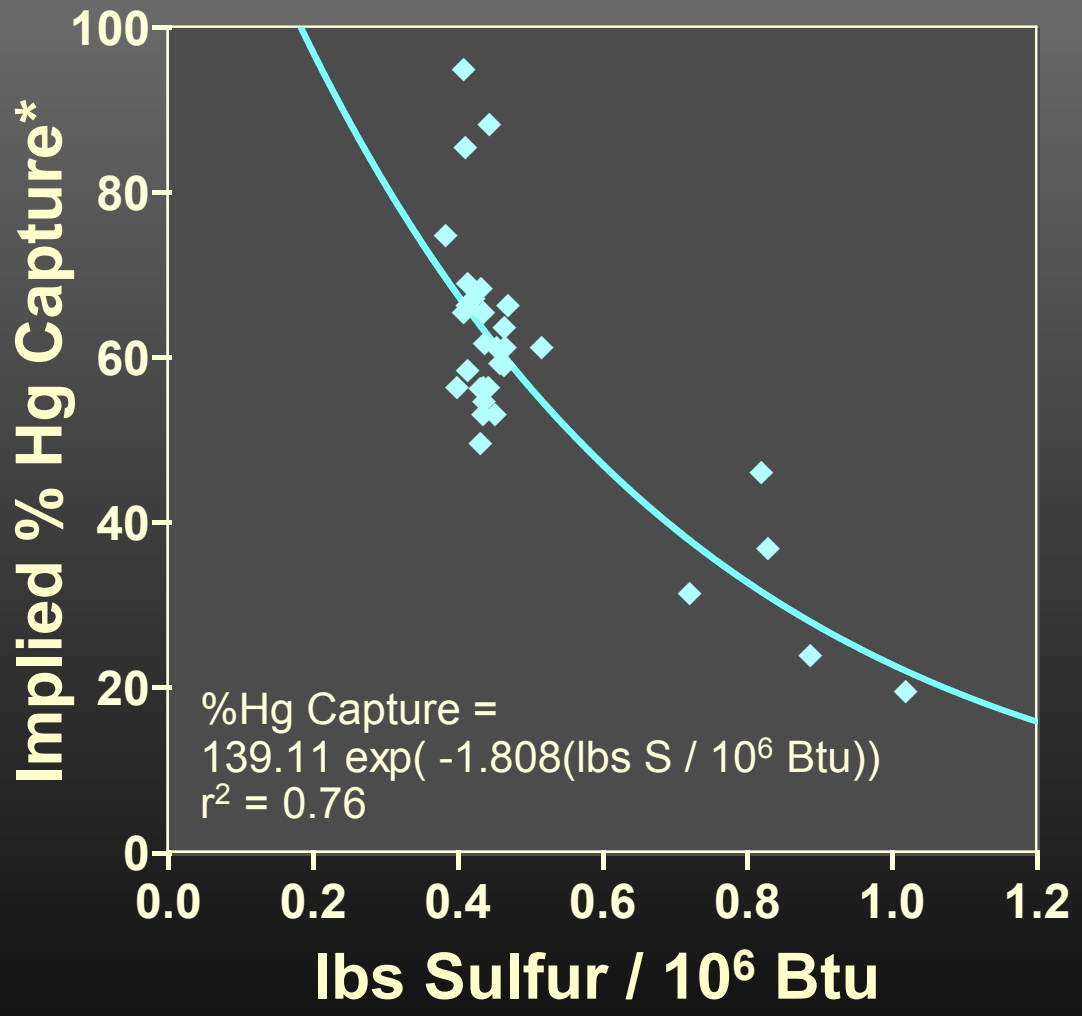
Declining mercury capture with increasing coal sulfur



Preliminary CEA data,

2 cold ESP units,

Points show weekly average values

+5% carbon in fly ash (average 11%)

* Capture estimated after Meij et al., (2002, J. Air & Waste Manage. Assoc., v.52, p. 912-917) assuming 80% FA, 20% BA fractionation.

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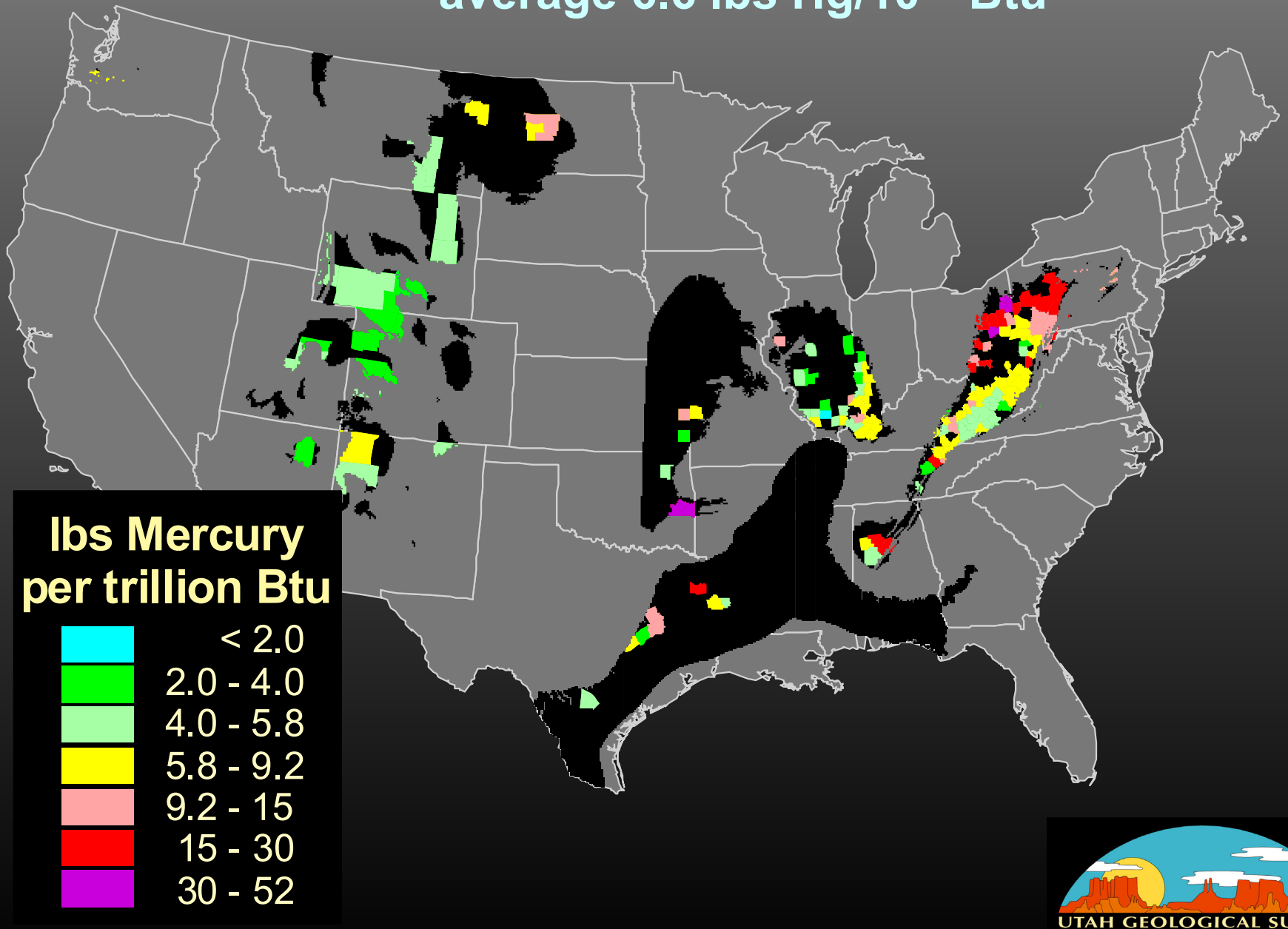
hot ESP Hg emissions, by coal origin

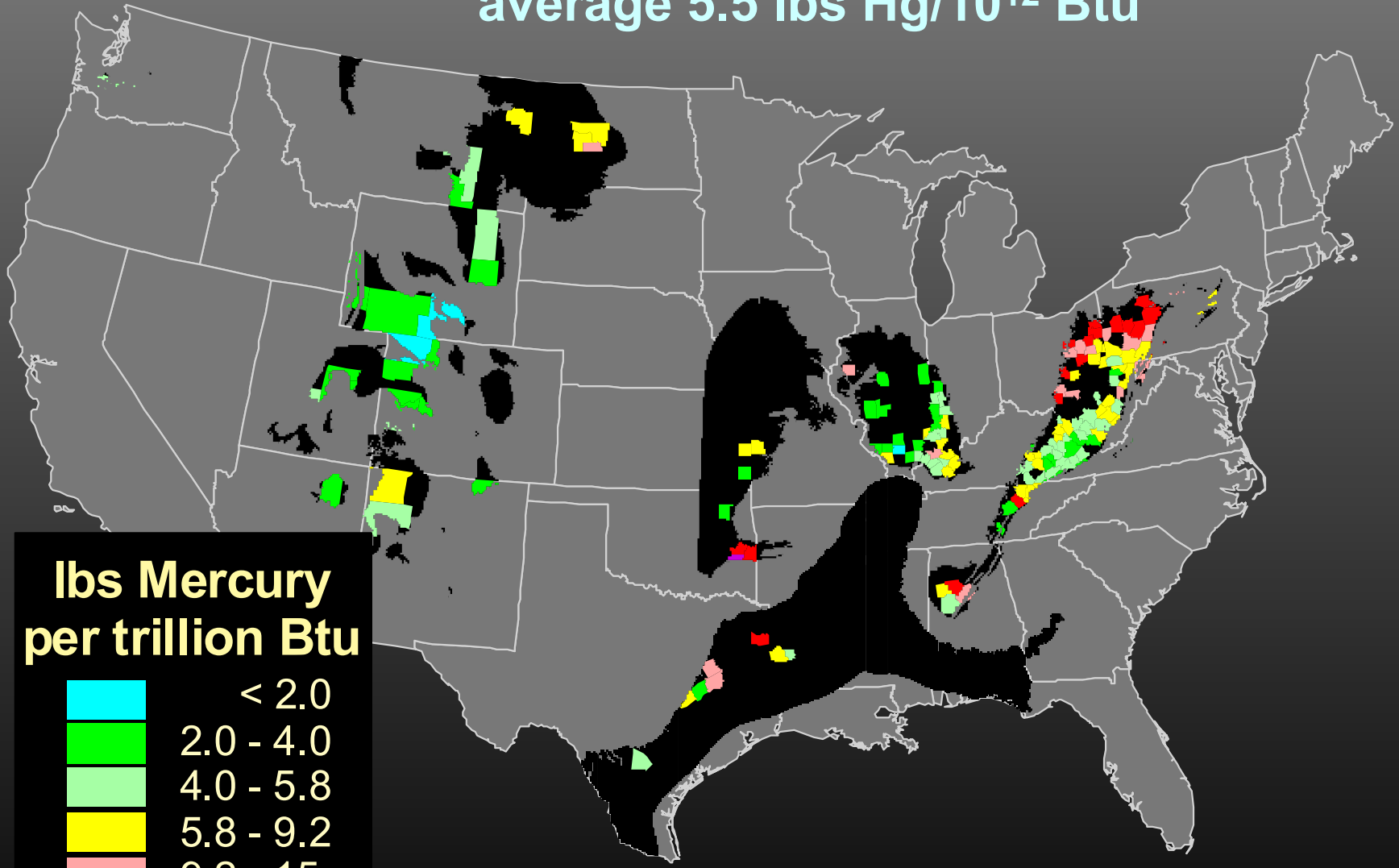
average 6.6 lbs Hg/10^{12} Btu



UTAH GEOLOGICAL SURVEY

cold ESP Hg emissions, by coal origin

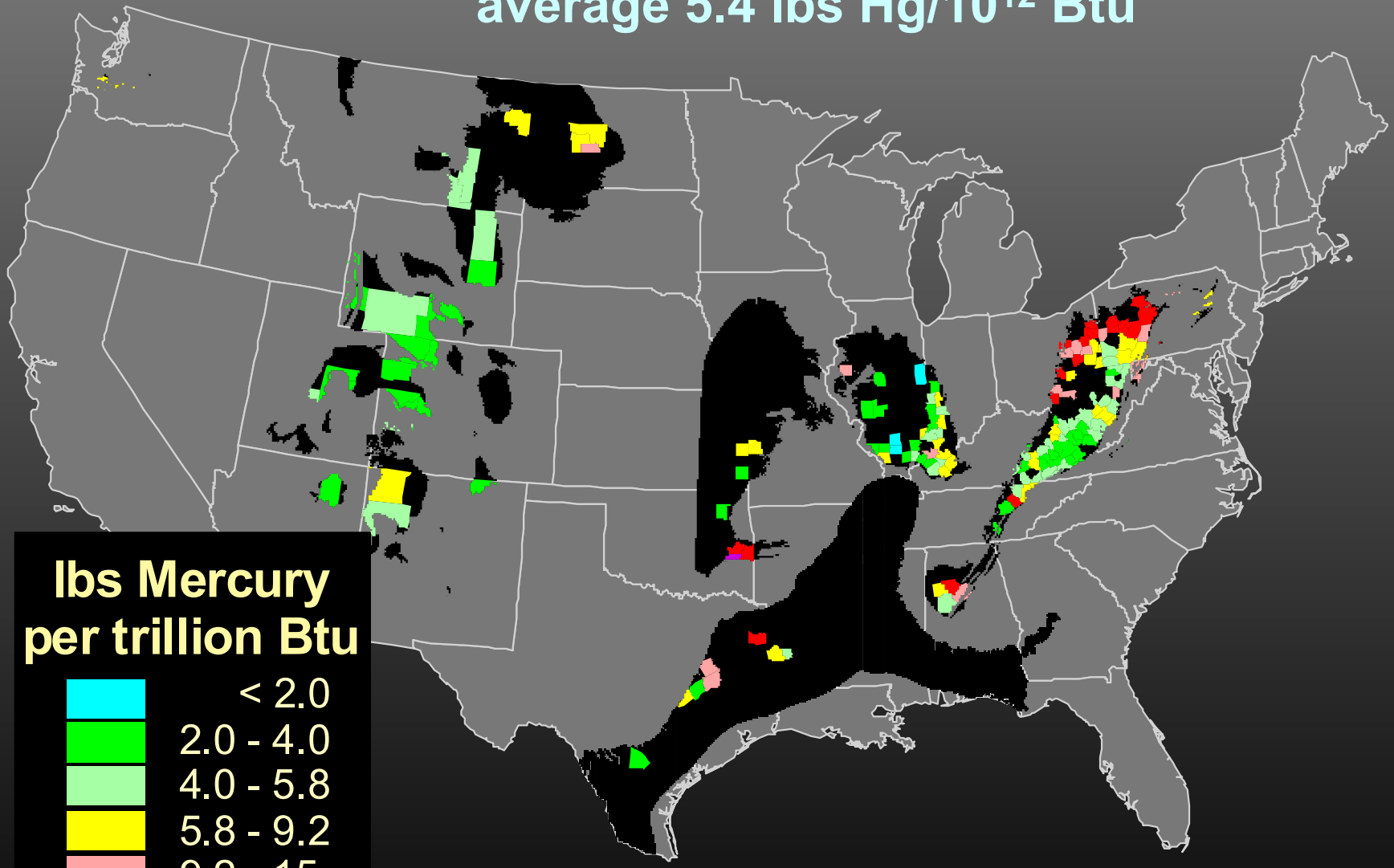
average 5.5 lbs Hg/10^{12} Btu



UTAH GEOLOGICAL SURVEY

hot ESP/FGD Hg emissions, by coal origin

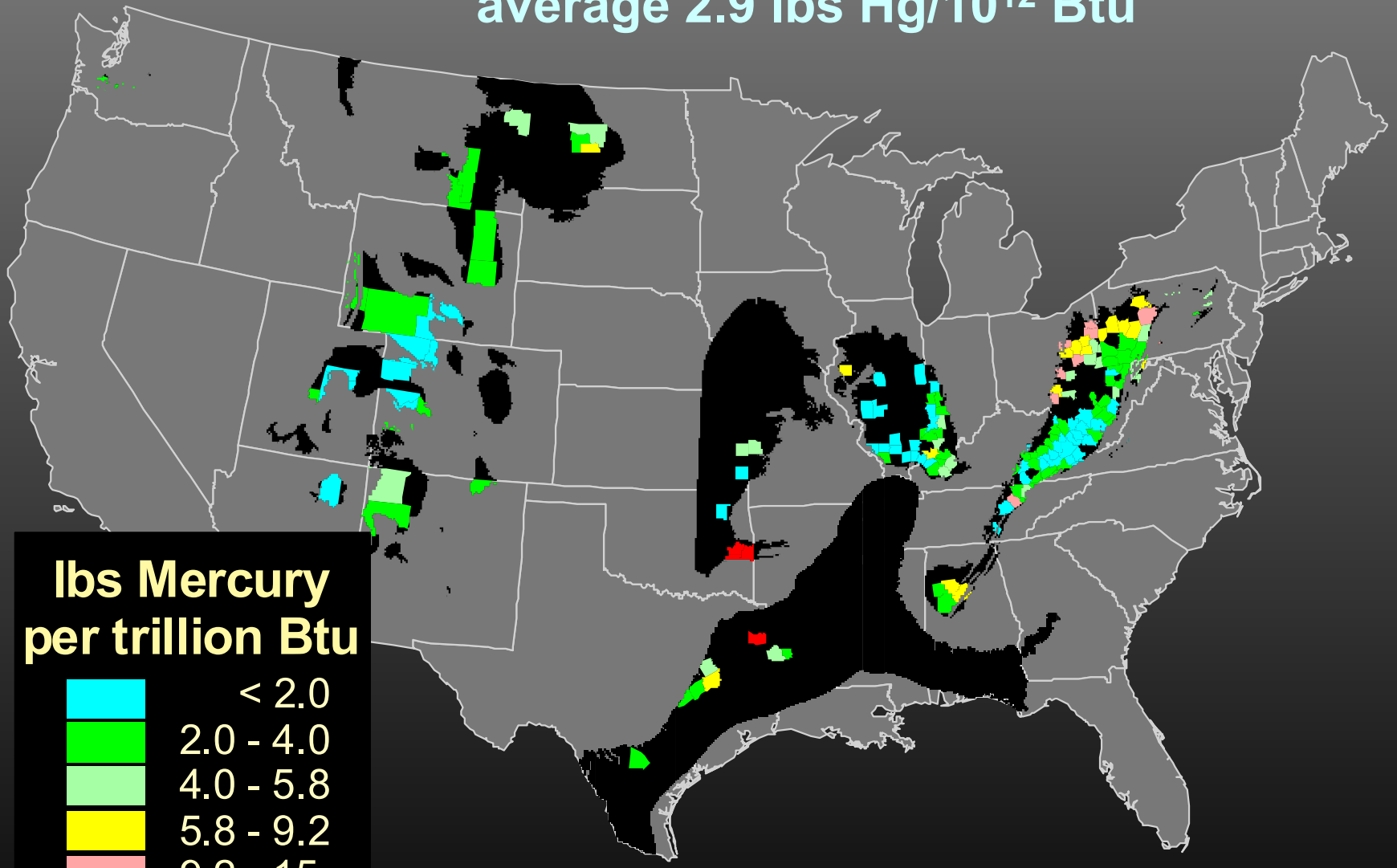
average 5.4 lbs Hg/10^{12} Btu



UTAH GEOLOGICAL SURVEY

cold ESP/FGD Hg emissions, by coal origin

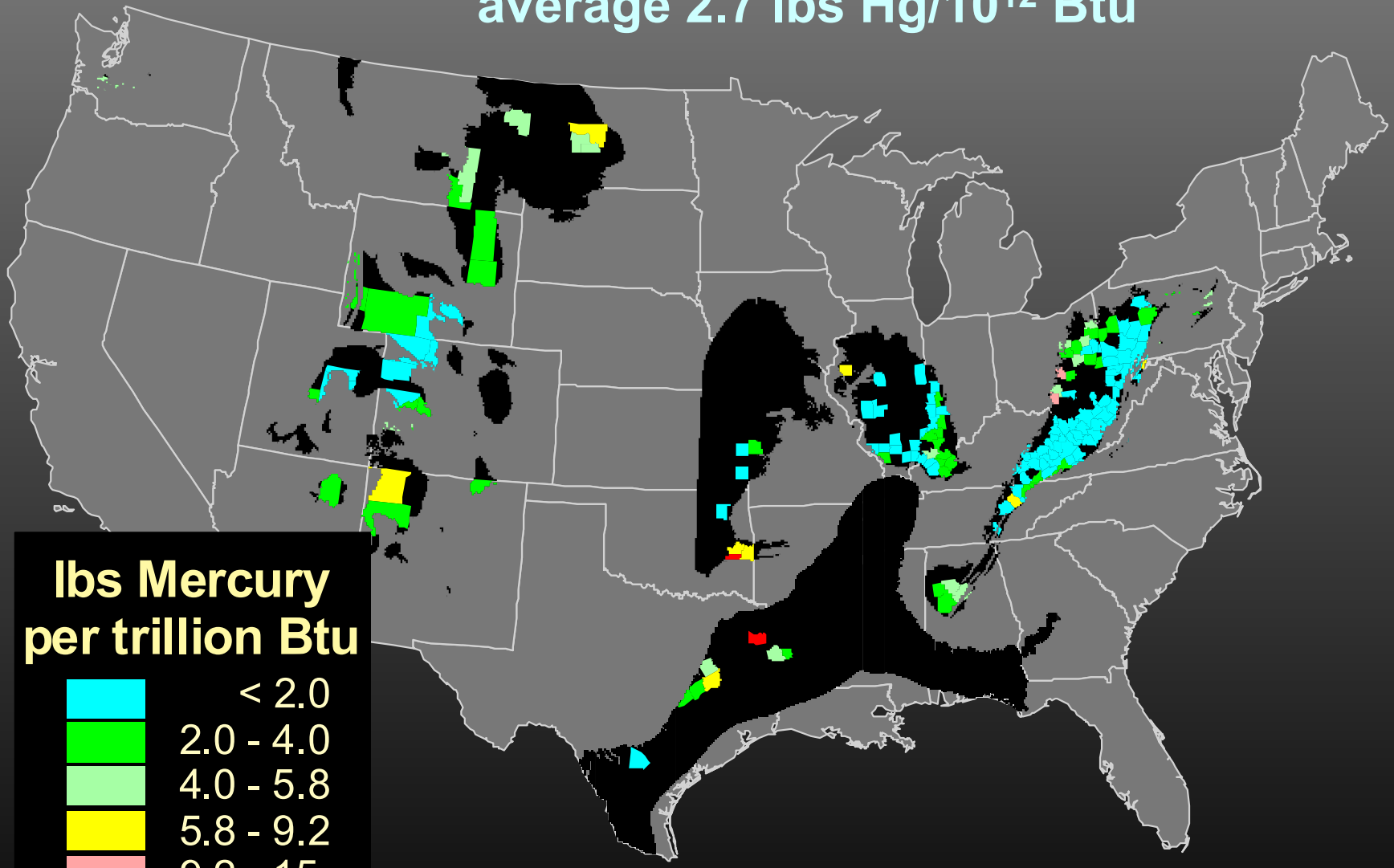
average 2.9 lbs Hg/10^{12} Btu



UTAH GEOLOGICAL SURVEY

SDA/FF Hg emissions, by coal origin

average 2.7 lbs Hg/10^{12} Btu



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Implications

Coal Washing

Useful where produced coal has similar or greater mercury levels than the in-ground coal

Coal Selection

Low mercury coal for hESP, cESP, hESP/FGD
High chlorine coal for cESP/FGD, SDA/FF

Coal Blending

For ESP/FGD and SDA/FF units, blend to between 500 and 1000 ppm Cl (e.g., PRB and deep IL basin)

Coal Sulfur

Low sulfur coal for situations where carbon in fly ash is used to improve mercury capture